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G02B 6/32

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G2J JGEB
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(58) Field of Search
UK CL (Edition M) G2J JGEB
INT CL^5 G02B

(54) Plano-convex lens for an optical fibre

(57) A lens 1 for an optical fibre includes a planar surface 3a to abut a free end 5a of the fibre and a convex lens surface 10 for producing a relatively narrow beam of light. Preferably the lens 10 comprises a plurality of frusto-conical surfaces 11, 12, 13, 14 each disposed at a different angle with respect to the optical axis 15. The lens may include an annular flange 6 by which it is mounted in plate 7 by clip 8.

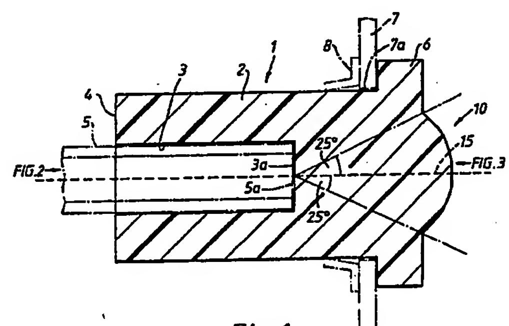

Fig. 1

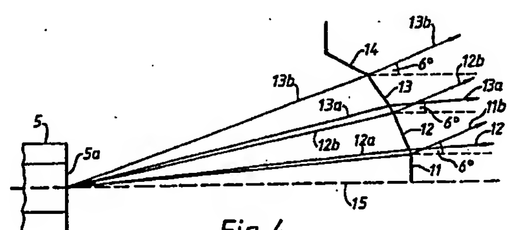

Fig. 4

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

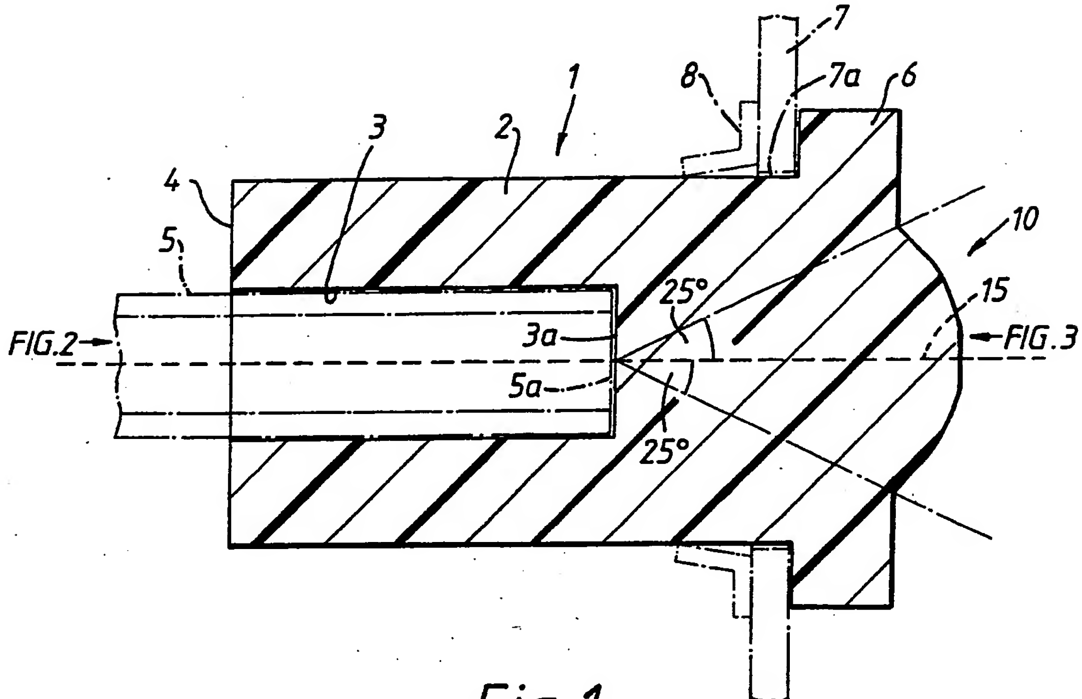

Fig.1

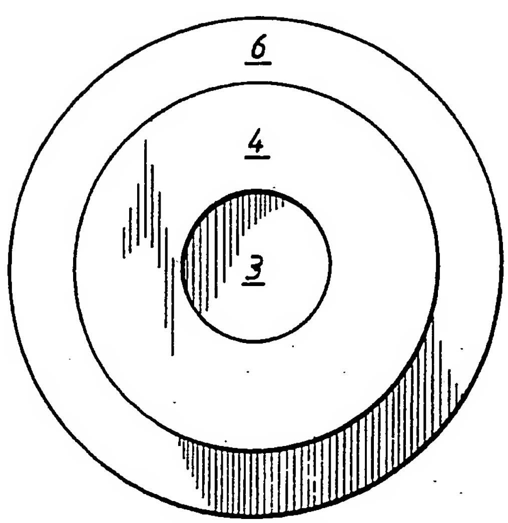

Fig. 2

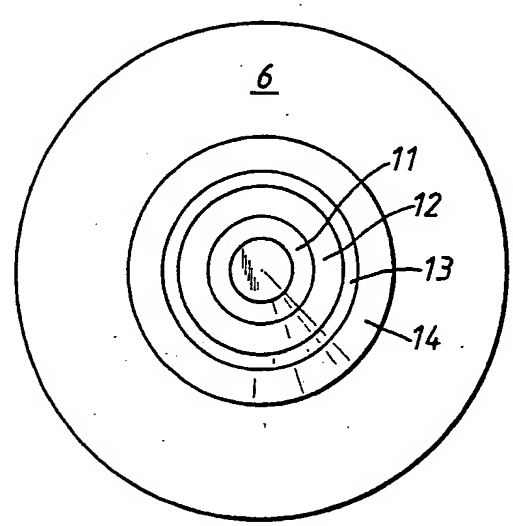

Fig.3

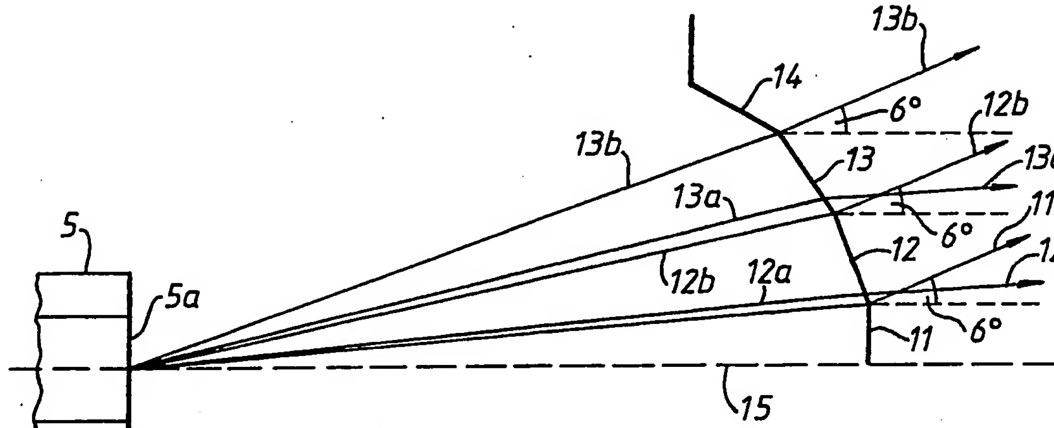

Fig. 4

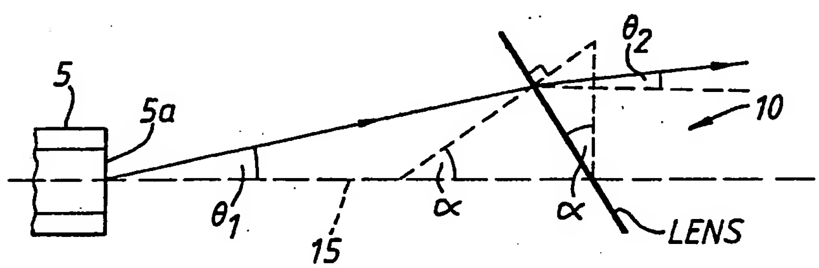

Fig. 5

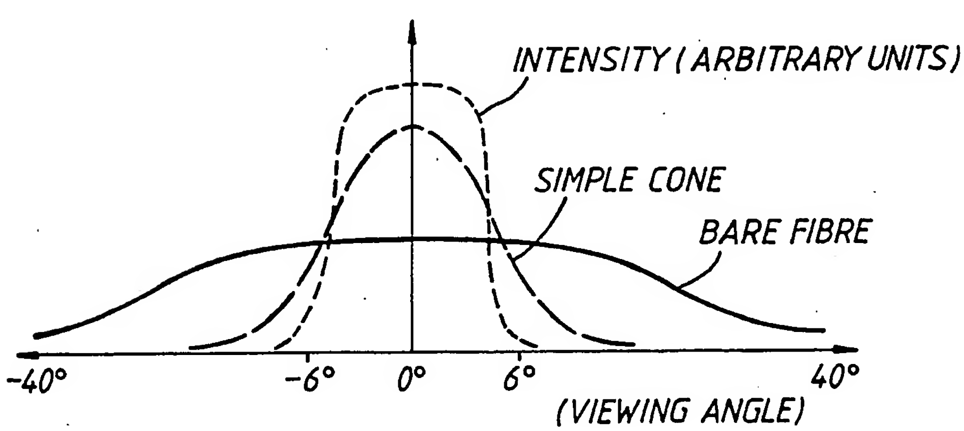

Fig. 6

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LENS FOR AN OPTICAL FIBRE

This invention relates to a lens for an optical fibre.

Recently, optical fibres have found a use within variable information displays of the type comprising a matrix array of liquid crystal shutters each disposed in front of a light source. By selectively shuttering the light the liquid crystal cells behave as pixels. Conveniently light is supplied by a light bulb which serves a plurality of liquid crystal cells by means of a bundle of optical fibres. It is important that such a display be as bright as possible and be readable over a range of viewing angles. For a motorway road sign application, United Kingdom Department of Transport Regulations require that such a sign have a predetermined value of intensity over a cone of semi-angle 6° around the optical axis. A simple cut fibre, in air, emits light over a semi-angle of about 40°. In order to produce a more concentrated beam it has been proposed to use a device of truncated conical shape, the narrow end of which is attached to the optical fibre and which operates using total internal reflection. The main problem with such a device is that those rays having relatively large off axis angles tend to undergo multiple internal reflections and it is difficult to design a device having uniform characteristics over a sufficiently wide range of viewing angles.

This invention provides a lens for an optical fibre, including a planar surface to abut a free end of the fibre and a convex lens surface for producing a relatively narrow beam from light emitted from the free end.

Because a lens is a refractive device, as opposed to the known devices which rely on total internal reflection, any individual ray only undergoes one change in direction upon exiting the lens as opposed to the multiple changes that can be undergone within the reflective prior art device.

It is preferred that the convex lens surface comprises a plurality of frusto-conical surfaces each disposed at a different angle with respect to the optical axis of the lens.

Such an arrangement can be relatively easy to design for a given specification and be straightforward to manufacture, such as by plastics moulding.

It is much preferred that the planar surface is disposed at the blind end of a socket dimensioned to receive and support the optical fibre.

The use of a socket as defined can ensure that the lens is particularly easy to secure in alignment with the optical axis of the fibre. Any pressure on the outside of the cable, e.g. from clamps or other alternative securing means, can cause light dispersion so that the use of a socket as defined prevents this occurence.

In order that the invention may be well understood an embodiment thereof will now be described by way of example with reference to the accompanying drawings, in which;

Figure 1 is a cross sectional view through a lens according to the invention;

Figure 2 is a plan view from the rear of the lens shown in Figure 1;

Figure 3 is a plan view from the front of the lens shown in Figure 1;

Figure 4 is a ray diagram showing a variety of rays passing through the lens surface;

Figure 5 is a ray diagram showing the design principles of the lens surface; and

Figure 6 is a graph showing the variation in intensity with angle for a lens according to the invention compared with that of a bare fibre and a prior art simple cone.

Referring to Figure 1 a lens 1 is integrally formed as by moulding from a transparent plastics material having a suitable refractive index. The lens 1 includes a shank portion 2 having a blind socket 3 extending inwardly from the rear most end face 4. The socket 3 is dimensioned to receive as a close fit an optical fibre 5, indicated by dotted outlines. The free end 5a of the fibre abuts the blind end 3a of the socket and is preferably attached by means of optical cement. The lens includes an annular flange 6 by which the lens can be mounted within a hole 7a in a support plate 7 and retained by means of a clip 8 at the rear.

An advantage of the invention is the straight forward way in which a display incorporating a matrix array of such lenses can be assembled. Lenses can be simply inserted and retained within the holes 7a and an optical fibre inserted and cemented within each respective socket 3. The socket ensures optical alignment and that no other means, e.g. clips, are required to hold the fibre in position.

A lens surface 10 is provided at the front of the device. The lens surface 10 is of generally convex shape and, as best seen in Figures 3 and 4 is divided into a plurality of frusto-conical surfaces 11, 12, 13 and 14 which are designed to function as described below. For a material having a refractive index of, for example, 1.493 light is emitted from a simple cut fibre over a cone of about semi-angle 25° with respect to the optical axis 15, and accordingly the lens is arranged to subtend that angle at the fibre. Referring now to Figure 4, a bundle of rays, 11, 12a, 12b, 13a, 13b, is shown exiting the end face 5a of the optical fibre 5. As the angle between the axis 15 and a ray emitted from the fibre end increases, its angle of emergence from the exit face of the lens is permitted to increase up to a fixed limit of, as shown, 6°. Ray 12a which exits near the bottom of face 12 emerges almost parallel to the optical axis 15, whereas ray 12b, which is at a relatively much greater angle exits through the same surface 12, but at an angle of 6°. Thereafter the slope of the exit face 13 is changed abruptly to redirect the rays nearly parallel to the axis, as shown by ray 13a. Face 13 continues until the exit angle again reaches 6°, as shown by ray 13b. The slope of the exit face is abruptly changed in this way until the majority of the emitted flux has been redirected, typically 90% is contained within a cone of semi angle 17.5° measured in the lens material. Thereafter the flux is permitted to spread into a cone

of semi angle 16°. In this way excessively sharp truncation of the beam is prevented which could hinder early aquisition of the sign image.

Using the above mentioned design rules the actual angles can be calculated using the straight forward application of Snells Law as will now be described with reference to Figure 5. For a lens of refractive index N, Snells Law yields;

$$\sin(\alpha - \theta_2) = n \sin(\alpha - \theta_1) \qquad \text{Equation 1}$$

Thus by expanding

$$\sin\alpha \cos\theta_2 - \cos\alpha \sin\theta_2 = n\,[\sin\alpha \cos\theta_1 - \cos\alpha \sin\theta_1]$$

Whence

$$\sin\alpha\,[\cos\theta_2 - n\cos\theta_1] = \cos\alpha\,[\sin\theta_2 - n\sin\theta_1]$$

$$\text{And so } \tan\alpha = \frac{\sin\theta_2 - n\sin\theta_1}{\cos\theta_2 - n\cos\theta_1} \qquad \text{Equation 2}$$

From Equation 1 we can obtain more conveniently:-

$$\theta_1 = \alpha - \sin^{-1}\frac{\sin(\alpha - \theta_2)}{n} \qquad \text{Equation 3}$$

Thus either using equation 2 to determine α, given θ_1 and the required value of θ_2, or by using equation 1, in the form of equation 3, to determine the maximum angle θ_1 subtended by the corner of a zone face from α and the required value of θ_2, all lens zones 11, 12, 13 and 14 may be defined.

The effects of the lens are shown in Figure 6 where a bare fibre, in air, emits light over a cone of semi-angle about 40°. A simple truncated cone has a relatively

"peaky" response and also significant levels of light are emitted even at quite large angles. With the device according to the invention, the intensity is fairly uniform, and high, upto about 6° on either side of the optical axis, but thereafter falls away quickly.

Although as described the lens surface comprise a plurality of frusto-conical surfaces, the surface could be of a more conventional smooth convex shape.

CLAIMS

1. A lens for an optical fibre including a planar surface to abut a free end of the fibre and a convex lens surface for producing a relatively narrow beam from light emitted from the free end.

2. A lens according to Claim 1, in which the convex lens surface comprises a plurality of frusto-conical surfaces each disposed at a different angle with respect to the optical axis of the lens.

3. A lens according to any preceding claim in which the planar surface is disposed at the blind end of a socket dimensioned to receive and support the optical fibre.

4. A lens according to any preceding claim including a flange disposed about the lens.

5. A lens according to any preceding claim which is arranged to emit light over a cone of semi-angle 6°.

6. A lens according to any preceding claim integrally formed from a plastics moulding.

7. A lens substantially as described with reference to the drawings.

Patents Act 1977 Examiner's report to the Comptroller under Section 17 (The Search report)	Application number GB 9403844.5
Relevant Technical Fields (i) UK Cl (Ed.M) G2J (JGEB) (ii) Int Cl (Ed.5) G02B	Search Examiner MR C J ROSS Date of completion of Search 21 MARCH 1994
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii)	Documents considered relevant following a search in respect of Claims :- 1-7

Categories of documents

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P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2180955 A	(GTE)	1 at least
X	GB 1569614	(STC)	1 at least
X	EP 0223282 A1	(PHILIPS)	1 at least
X	EP 0188392 A2	(ITT)	1 at least
X	EP 0175486 A1	(BT) See especially Figure 1	1 at least
X	EP 0063504 A1	(THOMSON) See especially Figures 1, 2	1 at least
X	EP 0025728 A1	(THOMSON) See especially Figures 1, 3	1 at least
X	WO 89/03273 A1	(KODAK) See especially Figure 5	1 at least
X	US 5097524	(WASSERMAN)	1 at least
X	US 4925267	(PLUMMER)	1 at least
X	US 4380365	(GROSS)	1 at least
X	US 4147402	(CHOWN)	1 at least

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